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Citizen science: A new direction in canine behavior research

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ABSTRACT

Researchers increasingly rely on members of the public to contribute to scientific projects—from collecting or identifying, to analyzing and disseminating data. The "citizen science" model proves useful to many thematically distinctive fields, like ornithology, astronomy, and phenology. The recent formalization of citizen science projects addresses technical issues related to volunteer participation—like data quality—so that citizen scientists can make longstanding, meaningful contributions to scientific projects. Since the late 1990s, canine science research has relied with greater frequency on the participation of the general public, particularly dog owners. These researchers do not typically consider the methods and technical issues that those conducting citizen science projects embrace and continue to investigate. As more canine science studies rely on public input, an in-depth knowledge of the benefits and challenges of citizen science can help produce relevant, high-quality data while increasing the general public's understanding of canine behavior and cognition as well as the scientific process. We examine the benefits and challenges of current citizen science models in an effort to enhance canine citizen science project preparation, execution, and dissemination.

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1. Introduction

People have observed the natural world since before recorded time. For centuries, professional scientists and the general public alike have asked scientific questions, collected data, and analyzed and explained findings (Miller-Rushing et al., 2012). The term 'citizen science' increased in usage toward the end of the 20th century to describe formalized public participation in scientific inquiry and research (Bonney, 1996; Bonney et al., 2009a). Citizen science encompasses the range of activities that generate new scientific knowledge or understanding as a result of participation by members of the public, "often in collaboration with or under the direction of professional scientists and scientific institutions" (OED, 2014). The term can be conceptualized broadly, to describe *any* type of public participation in scientific inquiry, or it can be used *narrowly* to suggest something more involved than simple participation, such as explicit data collection or analysis by volunteers (Bonney et al., 2014). Citizen science has flourished in recent years, in part due to the need for large-scale datasets, the public's increased access to technology and associated increases in communication capabilities, and funding agencies' emphasis on outreach and experience-based science education (Silvertown, 2009).

Citizen science can provide researchers with myriad benefits, including the ability to sample large spatial scales; use large quantities of citizen resources to collect labor-intensive data; gather data on private land; and examine data over long periods of time (Cohn, 2008; Dickinson et al., 2010). With increasing Internet access and technological advances, projects can readily engage volunteers on a global level (Bonney et al., 2014).

Additionally, partnerships between scientists and the general public can enhance the public's understanding and appreciation of the scientific process, the natural world, and advocacy for research (Cohn, 2008). Some citizen science projects focus heavily or entirely on public learning outcomes like knowledge acquisition and attitude or behavioral change. Leaders in the field of participatory science hope that citizen science practitioners not only consider public learning engagement, but also explicitly measure and test for learning outcomes (Bonney et al., 2009a).

Citizen science projects are increasing in number and appear across disciplines, from population genetics (e.g., https://genographic.nationalgeographic.com/) to ornithology (e.g., http://nestwatch.org/), quantum physics (e.g., http://scienceathome.org/), astronomy (e.g., http://stardustathome.ssl.berkeley.edu/), and entomology (e.g., http://schoolofants.org/), among others. Fields like zoology, ecology, phenology, entomology, and

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meteorology also rely more and more on public participation (Bonney et al., 2014). For particular areas of research, citizen science can be instrumental. For example, public participants provide ecologists with important geospatial data on species presence, absence, distribution, and abundance (Dickinson et al., 2010; Hochachka et al., 2012) and offer "many eyes" to locate rare organisms or track species (Dickinson et al., 2012). Given the desired scope and scale of ecological pursuits, ecologists could not perform comprehensive surveys or scans without public assistance.

Nonetheless, volunteer participation in scientific research poses challenges. For example, public participation projects are often subject to questions of quality assurance, a topic that garners considerable attention from leading citizen science practitioners (Bonney et al., 2014).

Canine science is a growing field with contributors from many disciplines incorporating a variety of methodological approaches. Contributors come from fields like psychology, ethology, veterinary behavior and medicine, animal sheltering, anthrozoology, genetics, ecology, archeology, and evolutionary biology, among others. While some researchers examine the thoughts, perceptions, or actions of companion dog owners (McMillan et al., 2011; Voith et al., 1992), others investigate behavioral underpinnings of the dog–human relationship (Cooper et al., 2003; Topál et al., 1998). Further, other researchers may collect biological samples to assess dog stress-related behavior and physiology (Denham et al., 2014; Dreschel and Granger, 2005), while others explore intraspecific social behaviors (Bekoff, 2001; Horowitz, 2009). The common denominator throughout is the use of domestic dogs—often companion dogs—and researchers can work as *de facto* citizen science facilitators.

Although existing public participation platforms provide useful roadmaps, little is currently known about the unique challenges facing canine-based citizen science projects. Additionally, canine researchers are not necessarily familiar with models of citizen science projects and the potential strengths and limitations of each. Here, we examine several benefits and challenges in current canine citizen science projects and provide recommendations for developing and implementing future projects. The potential of public participation projects depends on understanding their challenges. In particular, we review ways to enhance data quality and project success while supporting participant learning and science education. To inform our analysis of canine-focused projects, we elucidate strengths and weaknesses currently evident in citizen science projects generally. This analysis can fortify and expand the scope, validity, and rigor of canine citizen science projects while encouraging meaningful connections between professional researchers and the general public.

2. Citizen science design and implementation

Citizen science projects are generally placed in one of three categories: *contributory*, *collaborative*, or *co-created* (Bonney et al., 2009a). In contributory projects, professional researchers act as experiment architects, setting up the full project design, while citizens provide data by direct contribution or through passive use of citizen resources, such as online access to idle computer memory (the Skynet). Collaborative projects, on the other hand, offer the public a more hands-on experience of experiment design and analysis; scientists design the project, and citizens not only contribute data but also help sharpen experimental design, analyze data, and circulate experimental results. The category representing the greatest level of partnership and involvement between professional researchers and the general public, co-created, allows the public to not only work with scientists to design the project, but also to participate actively in all stages of the scientific process. The majority of citizen science projects are contributory, although projects can become increasingly collaborative if researchers build in flexibility. Projects vary in their objectives—such as data collection and hypothesis-testing, conservation and public interest, or improving science literacy—and objectives often shape project design. With the growth in scope, complexity, and sheer number of citizen science projects, field-wide self-audits have led to an increased emphasis on reviewing and fine-tuning citizen science approaches (Bonney et al., 2014).

2.1. Project preparation and participant motivation

Citizen science projects can benefit from interdisciplinary scientific teams (Bonney et al., 2009b). Team-approach proponents argue that, depending on the nature of the project, one discipline might not have all the necessary skills required. Accordingly, veteran citizen science practitioners stress the need for interdisciplinary relationships to cover project planning and development as well as data management and cyber-infrastructure (Newman et al., 2011). Protocols should be designed with institutional and federal regulations in mind and possess well-defined data acquisition methods with easily-understood, process-driven protocols that produce clear and useful data (Bonney et al., 2009b).

Obtaining a relevant sample of participants can be difficult, as the very nature of citizen science can attract one subset of the population while excluding another (Ess and Sudweeks, 2001; Newman et al., 2012). For example, collecting data using a smartphone application reduces the population to those who can afford smartphones or those who embrace smartphone technology, potentially excluding members of the public who cannot afford or have not adopted the technology. This does not mean, of course, that citizen science projects cannot rely on smartphones. However, if relevant conclusions depend on thorough representation of, for example, age or education level, these groups must be considered and drawn into project design.

A further consideration in successful project design is participant tracking. Tracking participant performance, or choosing not to, can impact data quality. For example, studies may decide whether each participant can contribute once or provide multiple contributions over time. In the latter, participant training or tracking can enable researchers to assess and identify over-representative data from a subject whose assessments are inaccurate or could introduce bias that skews results (Bird et al., 2014).

Projects should also consider participant motivation—how much can researchers ask of volunteers? If researchers ask too much, it is possible citizens will provide unfinished or non-comprehensive data. For example, Delaney et al. (2008) found that participants were particularly unlikely to provide all the information requested when data collection was overly challenging. This phenomenon affects project design and data collection (e.g., online surveys that save input after every question so that even incomplete surveys can provide data), as well as order of information sought (e.g., lead with more important queries so that if participants do resign, relevant data can be acquired prior to resignation).

Citizen science projects utilize a variety of participant motivation and reward strategies. Feedback and engagement prove more successful than 'altruistic' rewards like emphasizing that participant data is instrumental for scientific research and that volunteers can play a large role in advancing science (Hochachka et al., 2012). For example, eBird (http://ebird.org/content/ebird/) a citizen science project that engages global participants to collect data points on birds, reported that participation increased substantially when participants were able to track their bird records, sort their data, share their list with others, and visualize their data (Hochachka et al., 2012; Sullivan et al., 2009). Competitive elements can also increase participation, as eBird provides information on relative status of participation, such as the number of species a participant has seen. Foldit (http://fold.it/portal/) also uses a competitive approach. The online computer gaming framework recognizes 'players' with high scores accredited to their contributions to protein-folding puzzles (Khatib et al., 2011). Overall, direct engagement seems more effective than ideological or altruistic engagement.

2.2. Data quality, acquisition, and analysis

Citizen science projects often attract questions about data quality, and datasets have been described as "coarse" (Bonney et al., 2009b). A common concern is that participants have a wide range of skills, backgrounds and dedications that could generate "lesser-quality" data. However, the potential for amassing large datasets in citizen science projects could dilute the negative impact of more variable data (Bonney et al., 2009b).

To ensure that data obtained in citizen science projects are high-quality, researchers should outline clearly defined methods. Researchers should also incorporate data-validation procedures to reinforce project methodology (Bonter and Cooper, 2012; Newman et al., 2012). Below are common data-quality challenges and potential solutions that project designers often consider.

2.2.1. Decreased precision

When the general public, with a collectively unfocused knowledge base, contributes data to a project, precision might decrease. For example, requesting novices to contribute species identification can result in identification errors (Bird et al., 2014). Increased sample size could decrease precision errors in a dataset.

2.2.2. Sampling error

Mistakes introduced during data collection occur when observers differ in their ability to "detect, identify and quantify" the requested data (Bird et al., 2014). As with precision errors, increasing contribution quantity can offset sampling error, but researchers can also help overcome this error by providing clear definitions and instructions of what is to be sampled. For example, photographic guidelines or online 'help' resources can reduce sampling error. Simple, easy-to-follow sampling techniques can further reduce error. Exploration of possible volunteer responses through pilot studies and participant training are also key factors in obtaining a higher-quality dataset (Edgar and Stuart-Smith, 2009).

2.2.3. Bias

When designing citizen science projects, each field should identify the possible areas of bias, examine how such biases could potentially affect datasets, and explore ways to minimize or ward against it (Cooper et al., 2007; Yu et al., 2012). Bias can come in many different forms, such as species under-detection or "non-random distribution of effort" (Bird et al., 2014). Bias could even stem from observer type. In an unexpected example, moderately skilled observers were better at identifying birds from their calls than expert observers, who tended to claim incorrectly that they identified rare species (Farmer et al., 2012). Divers were found to incorrectly estimate fish size when underwater (Edgar et al., 2004). In another study, volunteers who were asked to characterize crabs as invasive or native improved their performance with age and education level (Delaney et al., 2008). Piloting can minimize bias by increasing awareness of project-specific issues, pre-determining relevant participant perceptions, providing specific training, or calibrating data prior to analysis. Because increasing sample size can reduce these risks but also has its own challenges, it is often suggested that "citizen science data will show general phenomena or patterns that must be examined further with smaller, more focused studies" (Bonney et al., 2009b). Overall, researchers and project designers should be wary of the product of bias when designing studies and interpreting the resulting data.

2.2.4. Data screening and quality control

Even with an easy-to-execute protocol and a large sample size, researchers can take steps to improve data quality through data screening and a quality-control procedure for data filtering and validation (Bonter and Cooper, 2012). Citizen science data contributors are a broad and plastic group, and projects should incorporate an initial or ongoing refining process to account for sampling errors. For example, researchers should consider subsampling contributor populations to determine uneven effort and identify and filter out repetitive contribution errors (Wiggins et al., 2011). A properly designed data filter can flag issues, and subsampling the population can allow for issues to be quickly identified and checked before they negatively impact data quality.

Researchers should be mindful of what type of assurances to apply to the data. Gardiner et al. (2012) suggests that data can be collected through *direct* or *verified* citizen science, where the former lacks verification, and in the latter, only data exposed to expert confirmation are analyzed. Both differ from traditional research approaches that tend to be more costly and have the longest lag time between data collection and dissemination but typically are considered more accurate. On the other hand, citizen science can be much less expensive and generate more data quickly, but, depending on the type of data collected and the assurances placed on the data (whether in direct or verified projects), accuracy might decrease (Gardiner et al., 2012).

Citizen science practitioners have begun cataloguing statistical tools, techniques and approaches useful for addressing challenges offered by citizen science datasets. Bird et al. (2014) suggest that GLM, GLMM, GAMM, and mixed-effects trees, among others, can be useful in addressing error and bias in datasets. For example, a study used a GLM approach when finding that "volunteers that were more confident performed better at species identifications," and another study incorporated the same approach to account for divers' overestimation of fish size (Bird et al., 2014). Citizen science projects can look to other datasets with similar challenges, like meta-analyses.

2.3. Participant outcomes

Citizen science projects have the potential to benefit participants. Effects can be evaluated by assessing participant scientific knowledge, science literacy, or, in some cases, project-associated attitude change, but not many studies explicitly track these effects. Brossard et al. (2005) found that participants in The Birdhouse Network, a project through the Cornell Lab of Ornithology where participants provided specific data from nest boxes, showed post-participation increased knowledge of bird biology, but they did not change reported attitudes toward science or the environment, or their understanding of the scientific process. These and other findings suggest that citizen science has the potential to impart basic fact-based knowledge but broad-scale changes—such as an understanding of the scientific process or changes in attitudes towards science—might not be apparent, relevant to participating communities, or easily measurable (Jordan et al., 2011). It is also plausible that studies do not explicitly (or successfully) impart such content to participants. By constructing anticipated impacts and measuring realized impacts, researchers can potentially improve the scope of citizen science participant outcomes (Bonney et al., 2009a).

3. Citizen science in canine behavior research

Canis familiaris research has grown considerably since the late 1990s, and the field relies more and more on nonscientists, including both the general public as well as dog owners specifically

(Bensky et al., 2013). This reliance on nonscientists stems in part from the intricate and intertwining lives of dogs and people. In many parts of the world, dogs sleep in peoples' beds and are perceived as companions, family members, and in some cases fellow workers (Hart, 1996; Miklósi, 2007). Importantly, the general public expresses interest in studies on canine behavior and cognition (Morell, 2009), and recent dog cognition studies rely heavily on companion dogs volunteered by their owners (Bensky et al., 2013). Given their ubiquity and peoples' connectedness with and interest in dogs, studies involving domestic dogs are ripe for inclusion in citizen science protocols.

Citizen science projects are not uniform in form or content, and selecting a project layout can be difficult. Here, we present three current citizen science models for canine researcher consideration, along with potential benefits and challenges to each. Most canine citizen science projects to date are contributory, although, if infrastructure allows, researchers could engage in more collaborative, or even co-created projects.

3.1. Model 1: Citizen-driven data acquisition

In this model, volunteers collect and provide data, and researchers receive volunteer-*interpreted* data but do not interact with the raw data. For example, Otter Spotter (http://www.riverotterecology.org/) is a project in the San Francisco Bay Area where people help researchers monitor the status and ecology of river otters, reporting location, date, and time of sighting, as well as sex and age characteristics and behaviors displayed. Researchers receive volunteers' reports but lack direct access to the actual otters observed. Participants of NestWatch, through The Cornell Lab of Ornithology (http://nestwatch.org/), provide researchers with data on bird reproductive biology, such as eggs laid, hatched, and surviving. In this model of citizen engagement, events might be too fleeting to provide researchers with recordable visual data. This model is common among contributory citizen science projects.

While heavily used in other areas of citizen science, few canine projects to date have embraced this model. One example is Dognition® (https://www.dognition.com/), a project where dog owners subscribe by financial membership to access and run a series of pre-set tests with their dog. Like Otter Spotter and NestWatch, Dognition® receives participant-interpreted data; researchers do not see the experiments being performed and instead receive owner reports. The tests gather measurements on a number of different cognitive domains, and Dognition® aims to receive data on a much larger scale than what is customarily achieved (Zimmer, 2013).

3.1.1. Model 1: Benefits

This form of citizen science has the potential to increase both citizen and academic knowledge of canine science questions as well as reach dog populations outside the immediate area of the research institution. Under this model, volunteers report their findings or observations directly to researchers, and as in other contributory projects, volunteers can report on a wide variety of topics not easily or readily accessed by researchers, for example feral or stray populations in remote areas, specific breeds, or topics related to ontogeny. Under this model, volunteers can report on fleeting events or occurrences (Dickinson et al., 2012). Skilled volunteers in other areas of citizen science have been shown to produce findings similar to those provided by experts (Delaney et al., 2008; Edgar and Stuart-Smith, 2009), and depending on the task—and with proper guidance—citizen scientists might provide valid, accurate, and reliable data.

3.1.2. Model 1: Challenges

Relying on raw data interpreted and reported by the public creates challenges, particularly for data quality. For example, reports on the number of dogs present at a dog park might be more accurate than owner reports about dog behavior at the dog park (Jackson, 2012). Researchers can consider the type of data being requested and the necessary steps to enhance data quality, such as emphasizing participant training, incorporating reliability pilot testing, assessing participant understanding of key concepts, or adding smart filters and flagging questionable data (Bonney et al., 2009b). For example, Dognition® offers a potentially useful FAQ section (http://support.dognition.com/knowledgebase), although it is unclear whether the focus is on helping subscribers complete tests or on promoting data quality and inter-participant consistency. NestWatch participants become certified NestWatchers prior to participation. Ideally, project designers consider the type of data that participants are being asked to produce and devise ways to instruct them in best collecting it.

Citizen science projects customarily institute data-quality checks, a practice of particular relevance for canine science projects relying on volunteer-interpreted data. For example, Hauser et al. (2011) found that trained experimenters and handlers both made errors in procedure execution during pointing experiments. While it was not explicitly examined whether dog behavior differed in trials with errors compared to trials without unforced errors, it is worth considering whether participant-collected data could be riddled with such issues, and if so, how they affect entire datasets. For example, many studies find that subtle owner or handler behavior can affect dog in-test behavior (Cook et al., 2014; Horn et al., 2013; Prato-Previde et al., 2008).

Model 1 projects can take steps to differentiate between typical and atypical data. Canine behavior and cognition studies led by trained experimenters readily flag data that are outside what is expected. For example, in two-way forced-choice tasks, where dogs make a choice to approach one of two items, dogs who display a side-bias—going right or left every time, independent of condition—are typically noted and dropped from analysis (Ward and Smuts, 2007; Cook et al., 2014). Testing for this or similar possibilities is important, particularly if raw video footage is not made available to researchers.

Projects requiring participants to look at dog behavior—whether reporting on specific actions or global body movements—should acknowledge that the general public is susceptible to reporting and interpretation errors. Williams et al. (2012) found that volunteer behavioral data collected on captive otters differed from a trained experimenter's results because volunteers did not follow the directions or report within the sampling period. On the other hand, primary-aged children instructed in Greylag goose behavioral observation performed on par with professional biologists (Didone et al., 2012). In canine research, members of the public may differ in their interpretation of and attention to dog behavior, sometimes based on their experiences with dogs (Wan et al., 2012). When considering behavior-sampling techniques in citizen science, certain sampling methods could be more or less difficult for observers to follow (Martin and Bateson, 2007).

Finally, when researchers do not have access to raw visual data from video or photographs, citizen science projects could be more conservative in what volunteers are asked to provide. For example, it might be better to ask for simple information like count data, rather than relying on volunteers to report accurately on complex dog behaviors or perform difficult protocols. If the requested data is too complex, creating filters or flagging data to discriminate high-quality from poor-quality data could be difficult or impossible. Projects lacking such validation procedures could emphasize proper training or even participant screening.

3.2. Model 2: Citizens provide unanalyzed raw data

In this model, volunteers provide raw data, and researchers analyze it. These types of projects are versatile in appearance and scope, and raw data could take the form of audio or video footage, photos, or biological samples, among other things. For example, Project: Play With Your Dog, organized by the Horowitz Dog Cognition Lab, requested that owners provide a short video of a person and dog playing together (Horowitz and Hecht, 2014). Participants generated the raw data per researcher instructions, uploaded the video to a secure website (viewable only to researchers), and could contribute a photo of their dog to a public 'Wall of Contributors.' Participants have also provided researchers investigating activity and impulsivity with dog buccal smears for DNA analysis (Wan et al., 2013). This study shares similarities with Sampling Your Home's Microbes (http://homes.yourwildlife.org/), a project where volunteers swab specific regions of their homes and send back the swabs for analysis (Dunn et al., 2013). Additionally, the Impulsivity Project through the University of Lincoln collects DNA samples from dog saliva to investigate factors contributing to aggressive impulsivity in dogs (http://www.uoldogtemperament.co.uk/dogpersonality/). Owners complete a Dog Impulsivity Assessment Scale (DIAS) (Wright et al., 2011), and both low- and high-scoring dogs contribute to DNA analysis.

3.2.1. Model 2: Benefits

Researchers gain direct access to participant-acquired data for analysis. Participants could provide raw footage (whether audio or video) of dogs in real-life scenarios that researchers do not generally have access to. Like many citizen science studies that access various spatial and temporal environments, participants can capture raw data and share it with researchers for direct analysis. With the expansion of accessible technology and the increase in places that people and dogs traverse, citizen scientists could capture dogs in a number of different environmental conditions, from animal-assisted therapy visits and dog training classes to dog skydiving or mountain climbing. As in Ákos et al. (2014), volunteers could place cameras and tracking devices on their dogs to provide researchers with data on dog social relationships and underlying movement of social groups. The public could capture dog–dog interactions or dog behavioral development in real time via live streaming or other video devices. In these instances, citizen scientists collect the data while researchers analyze and assess it essentially as if they had collected it themselves.

Nelson and Fijn (2013) describe YouTube as a fruitful arena for animal behavior research, particularly to access uncommon or novel behaviors. Burn (2011) relied on YouTube videos to investigate human response to dog tail chasing, selecting videos that met particular criteria along with control videos matched for breed. So as to not capture only the novel or exceptional, researchers could also request specific content be shared with researchers on YouTube or on other video sharing websites. By receiving visual data from participants, researchers have greater flexibility in data analysis and acquisition (Martin and Bateson, 2007).

3.2.2. Model 2: Challenges

In Model 2 projects, researchers have the potential to collect a larger amount of data. However, researchers will need time to analyze results and to be prepared for incomplete data or participants who do not follow directions. Depending on participant interest and project infrastructure, projects might need to accommodate many more participants than expected. To address these challenges, project managers could not only establish explicit standards for data inclusion, but also incentivize participants to follow instructions.

Model 2 projects can raise the question of selection bias. Not everyone is willing or able to capture and provide raw data, whether it be sharing dog biological samples or accessing technology to share pre-recorded videos (Ess and Sudweeks, 2001; Newman et al., 2012). Participants might not constitute a representative sample, although this question has not received explicit investigation in either lab- or more citizen science-based approaches to canine science. On the other hand, submissions received through both Model 1 and 2 designs have the potential to reach participants who might not participate in typical lab-based canine studies, or reach members of the public with differing social or cultural backgrounds (Horowitz and Hecht, 2014).

Additionally, providing participants with direct feedback or employing engagement strategies might be challenging because there could be a delay between data receipt and data analysis by researchers. Alternate strategies for participant engagement, such as a voluntary 'Wall of Contributors,' could be useful. Finally, providing researchers with raw data in the form of video or photographs could raise questions, particularly those related to participant privacy.

3.3. Model 3: Researchers provide content, and citizens analyze

In this final model of public participation, researchers provide content that volunteers evaluate. This model lends itself to a plethora of project formats and has included projects where participants tag wildlife in photos (Snapshot Serengeti, http://www.snapshotserengeti.org/), map neurons in the brain (Eyewire, https://eyewire.org/signup), and play puzzles that contribute to genetic disease research (Phylo, http://phylo.cs.mcgill.ca/#!/EN). In canine science projects, the applications are equally varied. For example, the public has described the emotional content of dog behavior (Wan et al., 2012), and they have characterized general sounds (http://www.inflab.bme.hu/~viktor/soundrating/index.html) (Faragó and Marx, 2014) as well as canid vocalizations (http://howlcoder.appspot.com/).

3.3.1. Model 3: Benefits

In this model, researchers essentially increase their manpower by relying on volunteer assistance to code or find patterns in data (e.g., Eyewire, Snapshot Serengeti, and The Canid Howl Project). Other projects solicit participants' non-expert opinions, such as describing dog emotional state from video footage. Depending on the project, this type of public involvement could provide researchers with more time to analyze and disseminate data if volunteers are able to process it.

3.3.2. Model 3: Challenges

Challenges will vary depending on the requested task. Participant training and knowledge testing are imperative to project success, particularly if there are "right" or "wrong" answers, as in Snapshot Serengeti where participants tag wildlife in photos.

To overcome such challenges, quality checks can isolate volunteers who have a desired level of accuracy and precision in their work. This sort of participant tracking allows testing for inter- and intra-observer reliability in volunteers (Burghardt et al., 2012). Researchers could also build measures of confidence into datasets, for example conducting inter-observer reliability on a predetermined subset. As mentioned earlier, volunteer registration and tracking could assist this type of project in detecting whether a repeated user is skewing the data.

4. Canine citizen science: a public partnership

4.1. Exploring current practices

Currently, most researchers studying domestic dogs do not rely on purpose-bred dogs, as was typical of prior studies (Scott and Fuller, 1965). Although 21st-century researchers do investigate shelter dogs, village dogs, and feral populations (e.g., Boitani et al., 1996; Ortolani et al., 2009; Udell et al., 2010), companion dogs housed and fed by owners increasingly act as study participants. Cooperation and interest from nonscientists, particularly dog owners, greatly benefit these research programs. Canine science studies are often lab-based and conducted "in-house" by research groups around the globe (see Bensky et al., 2013) as well as by veterinary practitioners (Voith et al., 1992).

Lab-based researchers often maintain websites where owners can register their dog and be contacted to participate in studies (e.g., New York City: http://bit.ly/1w3ZDpT, Vienna: http://bit.ly/11d7fK7 and Lexington, KY: http://bit.ly/1FxNNr3). The role of the owner in experiments ranges from totally absent to a passive handler or active participant (Miklósi, 2007). These researcher-guided studies provide a more controlled but less traditional approach to citizen science. Owners supply dogs as subjects but are not involved in collecting or interpreting data. Rather, owner participants can better be described as facilitating research. In some cases, owners complete questionnaires and might be study subjects themselves (e.g., Jones and Josephs, 2006; Kis et al., 2012). While owner contributions are valued highly, the lab-based approach typically omits participant benefits and learning outcomes, two notable aspects of citizen science. Lab-based studies incorporating dogs and their owners are more similar to infant studies where parents facilitate research by bringing their child for testing and possibly participating in the experiment themselves. In paradigms where participants facilitate research, appreciation is often extended during the post-study debriefing as well as in Acknowledgement sections. Regardless, these types of studies differ in form and content from the models of citizen science described in Section 3.

Questionnaire-based studies are also common in canine science and raise similar considerations. Participants stem from a variety of populations such as university students (e.g., Fratkin and Baker, 2013), members of the general public (King et al., 2009), or a subset of the public, like dog owners (e.g., Voith et al., 1992; Hsu and Serpell, 2003). Interestingly, questionnaire studies, like the Monash Canine Personality Questionnaire-Revised (MCPQ-R) and the Canine Behavioral Assessment and Research Questionnaire (C-BARQ) can share similarities with Model 1-type projects where researchers receive owner reports of dog behavior without direct verification, but testing of instrument reliability and validity is possible (Hsu and Serpell, 2003; Ley et al., 2009). Generally speaking, questionnaire participants facilitate research but are somewhat outside the realm of citizen science participants contributing their efforts.

To date, most published canine science studies stem from lab- or questionnaire-based paradigms. While contributions from people, their dogs, and members of the general public are instrumental, they do not necessarily embody traditional aspects of citizen science, like "collecting, categorizing, transcribing, or analyzing scientific data" (Bonney et al., 2014). Given the dearth of published canine projects relying on public participatory models, the success of citizen science over more traditional lab- or questionnaire-based approaches remains to be seen. In other fields, citizen science approaches prove essential. For example, Cooper et al. (2014) found that citizen scientists reporting on migratory birds have been integral to research into phenological shifts and, thereby, global climate change. Although the potential benefits of canine citizen science models are considerable, they have yet to drive the canine science literature forward.

4.2. Responsibilities to participants

Attempted citizen science projects might not always accomplish the goals of breaking down barriers and opening scientific experiences to non-professionals. Conflating research and a business model is one potential pitfall. For example, Dognition® describes itself as "a leading example of 'citizen science' - research developed by leading scientists that can be conducted by everyone, not just people with Ph.D.s" (https://www.dognition.com/explore-the-science). It is the only example in this field of a for-profit product—with researcher affiliations—that charges a fee to access interactive games to play with their dogs. Variations on this issue appear in other contexts. While entrance fees are not common for citizen science projects, some require gear for participation, such as a computer, binoculars, or a headlamp. Participants in The Birdhouse Network paid to participate in authentic research about bird biology, and they received nest boxes and detailed scientific protocols so participant findings could contribute to peer-reviewed articles (Cooper et al., 2006). Some citizen science volunteers participate through ecotourism or volunteer tourism; for example, Earthwatch participants pay to join global expeditions and act as field assistants contributing to research. Earthwatch participants are trained in the specifics of their data collection—which are exposed to reliability checks—and participant data have contributed to policy development (Brightsmith et al., 2008; Crabbe, 2012). Citizen science has been described as "an activity that is potentially available to all, not just a privileged few" (Silvertown, 2009), and questions remain about the ethics of attaching a "citizen science" label to fee-based products.

In addition, citizen science projects should provide experiences that retain the hallmarks of scientific merit (Dickinson et al., 2012). Projects need not necessarily strive for publication in peer-reviewed journals, but projects should be accurate representations of the scientific endeavor. The Dognition® test battery reifies experimental paradigms that are being modified and debated in the literature, such as studies relating to concepts like empathy (e.g., Custance and Mayer, 2012; Joly-Mascheroni et al., 2008) and reasoning (e.g., Agnetta et al., 2000; Erdőhegyi et al., 2007). The science of dog cognition is still in its early stages. Packaging ongoing research as conclusive could give participants a false sense of the true meanings of their individual "results," as well as the import of their participation.

While participants and researchers can both benefit from engagement strategies, projects should not sacrifice science bona fides. Gamification and data visualization techniques incentivize participation but can be taken to extremes. For instance, Dognition® participants receive dog "cognitive profiles" based on a person's report of dog in-test performance. Reports are based on games said to measure empathy, communication, cunning, memory, and reasoning; based on performance in these five dimensions, dogs are placed into one of nine profiles, such as Ace, Maverick, and Charmer. These "profiles" might have entertainment value but are not derived from empirical studies. By contrast, there are numerous empirical studies characterizing dog temperament and personality; these studies include reports of accuracy (Gosling et al., 2003), cross-situational stability (Svartberg et al., 2005) as well as reliability and validity (Hsu and Serpell, 2003). Importantly, studies to date have not produced individualized dog profiles derived from "cognitive game" performance. A major part of citizen science is connecting "authentic scientific research with science education" (Dickinson et al., 2012), raising the question whether it is appropriate to provide participants with profiles not derived from published studies and that read more like anthropomorphic astrological charts.

4.3. Canine citizen science: future considerations

While citizen science projects could rely on the public to act as willing workhorses, active public engagement at multiple, substantive levels remains a major focus of the field (Bonney et al., 2014). The undercurrent of citizen science focuses on including nonscientists in knowledge-acquisition while also increasing participant understanding of scientific objectives and processes, not simply as generators or analyzers of data. Canine-focused projects embracing public participation models could provide opportunities for learning about dog behavior, dog bite prevention, dog biology, and cognition, as well as indicators of good welfare.

While citizen science projects have the potential to add useful, novel data to canine research, there are currently few published studies in this field that have embraced traditional citizen science approaches. Canine researchers evaluating citizen science models could consider unique ways to involve the public that expand beyond typical lab- or questionnaire-based approaches.

Data quality remain a notable concern, and researchers should acknowledge and address possible pitfalls, error, and bias in datasets. Self-audits and self-checks play a large role in citizen science projects. Animal behavior researchers recently critically examined the lack of bias minimization techniques used in their field, noting that the practice of inter-observer reliability is implemented considerably more frequently in infant behavior journals than animal behavior journals (Burghardt et al., 2012). This phenomenon warrants similar attention when gathering and collecting canine citizen science data.

Citizen science projects continue to grow across disciplines (Hecht and Cooper, 2014), and locating and posting projects is increasingly easy thanks to aggregating websites like Citizen Science Central: http://www.birds.cornell.edu/citscitoolkit/, CitSci: http://www.citsci.org/, Zooniverse: https://www.zooniverse.org/, SciStarter: http://scistarter.com/index.html, and Scientific American: http://www.scientificamerican.com/citizen-science/, among others. Coverage of citizen science projects and the field at large are available on blogs like PLOS: http://blogs.plos.org/citizensci/ and Discover: http://blogs.discovermagazine.com/citizen-science-salon/. Professionalization of the field is evident in the development of local and international organizations that focus on the practice, implementation and effects of public participation projects. Organizations include the Citizen Science Network Australia: http://csna.gaiaresources.com.au/wordpress/, European Citizen Science Association: http://ecsa.biodiv.naturkundemuseum-berlin.de/, and the Citizen Science Association: http://citizenscienceassociation.org/. Canine science practitioners considering using the label "citizen science" can consult these groups to assess methods and outcomes, both for scientific quality and participant benefit.

5. Conclusion

Each year, more canine citizen science projects make their debut. With proper planning and an in-depth knowledge of the benefits and challenges of each type of project, researchers can design projects that produce relevant, high-quality data that enhance the scientific understanding of canines and the public's understanding and appreciation of the scientific process.

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